Broiler Responsiveness (Ross $\times$ 708) to Diets Varying in Amino Acid Density[1,2,3]

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ABSTRACT Sex-separate male and female broilers (2,592 broilers; Ross $\times$ 708) were placed in 144 floor pens (12 replications per treatment) and fed diets containing high (H) and moderate (M) amino acid density from 1 to 55 d of age. Diets were formulated using ileal digestible amino acid ratios to Lys. Six dietary treatment combinations (MMMMM, HMMMM, HHMMM, HHHMM, HHHHM, and HHHHH) were implemented in 5 diet phases (1 to 5, 6 to 14, 15 to 35, 36 to 45, and 46 to 55 d of age). Male birds were heavier ($P \leq 0.05$) and had lower ($P \leq 0.05$) feed conversion, abdominal fat, and breast yield than female birds. Birds fed H diets in the first 3 phases had optimal ($P \leq 0.05$) BW and feed conversion (d 35, and 45), but optimal ($P \leq 0.05$) feed conversion at d 55 warranted H diets in all phases. Breast meat (d 35) and carcass (d 55) relative to BW were highest ($P \leq 0.05$) in birds fed H diets in the first 3 phases; however, differences in 55 d breast meat yield did not occur. Results indicate that amino acid needs of Ross $\times$ 708 broilers are most critical from 1 to 35 d of age. Predicted economic margins were advantageous in birds fed H diets resulting in \$0.12 and \$0.05/bird more income over feed costs at 35 and 55 d, respectively, in comparison with birds fed M diets.

(*Key words*: amino acid, broiler, nutrient density, carcass traits)

2005 Poultry Science 84:1389–1396

INTRODUCTION

Growth rates of some newly developed modern commercial broilers have a tendency to be reduced, whereas proportions of carcass yields are increased in comparison with existing strains of commercial broilers from similar genetic lines. Delineating amino acid needs and responsiveness throughout growth in modern commercial broiler strains is of interest to optimize saleable meat in a profitable manner. Hence, in order to optimize economic returns, dietary amino acids should be fed in a strain-specific manner (Smith and Pesti, 1998). Knowledge of the time period in a broiler's life when amino acid needs are greatest in terms of productive growth is critical so that amino acid patterns can be adjusted in an efficient manner. Meeting amino acid needs represents a large portion of diet costs, and overformulating is costly whereas underformulating may negate economic returns due to suboptimal growth and meat yields. Kidd et al. (2004) conducted nutrient density research with a modern commercial broiler (Ross $\times$ 508) and indicated that amino acid needs were most critical early in the bird's life for optimization of breast meat yield later in the bird's life. Furthermore, feeding more amino acids early in a bird's life is economically advantageous because feed intake is low and potential growth improvements are high. In this study, Ross $\times$ 708 male and female broilers were fed diets formulated to high (H) or moderate (M) digestible amino acid levels in a ratio to Lys in various feeding phases to assess subsequent growth performance and carcass yields. A second objective of this study was to construct an economic program to compare income over feed costs in birds fed diets varying in amino acid density.

MATERIALS AND METHODS

Birds and Management

Ross $\times$ 708 male and female chicks (1,296 per gender) were obtained from a commercial hatchery and placed

Received for publication March 17, 2005.
Accepted for publication June 15, 2005.
[1]This is Journal Article Number J-10680 from the Mississippi Agricultural and Forestry Experiment Station.
[2]Use of trade names in this publication does not imply endorsement by the Mississippi Agricultural and Forestry Experiment Station of the products, nor similar ones not mentioned.
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Abbreviation key: H = high amino acid density; M = moderate amino acid density.

TABLE 1. Test diets (%) formulated to have high (H) or moderate (M) amino acid levels from 1 to 55 d[1]

Ingredients	1 to 5 d		6 to 14 d		15 to 35 d		36 to 45 d		46 to 55 d	
	H	M	H	M	H	M	H	M	H	M
Corn	52.30	59.58	54.85	62.05	61.24	67.41	61.73	67.63	62.71	68.40
Soybean meal	35.20	29.04	32.80	26.65	26.80	21.57	26.03	21.06	24.64	19.82
Poultry meal	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Poultry fat	4.05	2.84	4.03	2.84	3.80	2.77	4.47	3.49	5.13	4.19
Dicalcium P	1.30	1.34	1.21	1.25	1.09	1.13	0.99	1.03	0.84	0.87
Limestone	0.94	0.96	0.90	0.92	0.85	0.87	0.81	0.82	0.75	0.76
NaCl	0.46	0.46	0.46	0.47	0.46	0.46	0.47	0.46	0.47	0.47
Premix[2]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
DL-Met	0.26	0.22	0.24	0.21	0.21	0.18	0.20	0.15	0.19	0.15
L-Lys SO_4	0.18	0.23	0.20	0.27	0.23	0.27	0.03	0.08	0.01	0.07
L-Thr	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Sacox 60[3]	0.05	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.00
Choline Cl	0.01	0.03	0.01	0.03	0.01	0.03	0.01	0.02	0.00	0.01
Anal.[4] and calculated composition										
ME, kcal/kg	3,075	3,075	3,100	3,100	3,150	3,150	3,200	3,200	3,250	3,250
Anal. CP, %	22.62	20.65	22.41	20.49	20.13	17.28	20.49	18.85	17.82	16.51
Anal. Lys, %	1.38	1.28	1.36	1.24	1.23	1.05	1.13	1.06	1.09	1.01
Anal. TSAA, %	0.93	0.87	0.93	0.85	0.83	0.75	0.83	0.76	0.74	0.67
Anal. Thr, %	0.87	0.80	0.87	0.78	0.77	0.66	0.79	0.74	0.69	0.64
Anal. Ile, %	0.92	0.85	0.92	0.82	0.82	0.67	0.83	0.76	0.72	0.64
Anal. Val, %	1.04	0.98	1.04	0.94	0.93	0.78	0.95	0.87	0.83	0.75
Anal. Arg, %	1.54	1.39	1.53	1.35	1.34	1.11	1.36	1.25	1.19	1.09
Anal. Leu, %	1.78	1.65	1.83	1.68	1.63	1.41	1.68	1.60	1.39	1.29
Ca, %	0.94	0.94	0.90	0.90	0.84	0.84	0.80	0.80	0.74	0.74
Available P, %	0.47	0.47	0.45	0.45	0.42	0.42	0.40	0.40	0.37	0.37
Na, %	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Choline, mg/kg	1,550	1,550	1,500	1,500	1,400	1,400	1,300	1,300	1,256	1,200
DEB, mEq/kg[5]	226	201	216	191	190	170	187	167	181	161

[1]Diets were formulated using digestible amino acids minimums calculated from coefficients taken from Lemme et al. (2004) to create H and M nutrient variations.

[2]Premix provided the following per kilogram of diet: vitamin A (vitamin A acetate) 7,718 IU; cholecalciferol 2,200 IU; vitamin E (source unspecified) 10 IU; menadione, 0.9 mg; B_{12}, 11 μg; choline, 379 mg; riboflavin, 5.0 mg; niacin, 33 mg; D-biotin, 0.06 mg; pyridoxine, 0.9 mg; ethoxyquin, 28 mg; manganese, 55 mg; zinc, 50 mg; iron, 28 mg; copper, 7 mg; iodine, 1 mg; selenium, 0.2 mg.

[3]Anal. = analyzed. Sacox 60 provided 60 g/t of salinomycin for control of coccidiosis.

[4]Amino acid analysis was performed on composite samples of diets after acid hydrolysis (Degussa Corp., Hanau, Germany).

[5]Dietary electrolyte balance represents dietary Na + K − Cl in mEq/kg of diet.

gender separate in 144 floor pens. Upon arrival to the research facility, the chicks had been vaccinated for Marek's virus, Newcastle disease virus, and infectious bronchitis virus. The research facility was a solid-sided house containing pens measuring 1.35 m^2 on a concrete floor. Pens were heated with an electric lamp, in addition to whole-house gas brooding, and contained one pan feeder, a nipple drinker line (5 nipple waterers per pen), and new soft-wood shavings. From d 1 to 5, supplemental pan feeders were placed in each pen to assure good feed consumption. Feed and water were available to the birds for ad libitum consumption. The lighting program consisted of 23 h of light at 30 lx from d 1 to 7, 20 h of light at 5 lx from 8 to 44 d, and 23 h of light at 5 lx from d 45 to 55. Temperature was maintained at 32°C from 1 to 7 d, and decreased 3°C in 7-d increments until 20°C was achieved. Husbandry practices were in accordance with the Guide for the Care and Use of Agriculture Animals in Agricultural Research and Teaching (FASS, 1991).

Design and Dietary Treatments

The least-cost-formulated diets (Table 1) contained a nutrient matrix in linear programming that specified ME, Ca, available P, Na, choline, and dietary electrolyte balance. In addition, the nutrient matrix contained digestible amino acid minimums for Lys, TSAA, Thr, Ile, Val, Arg, Trp, and Leu from previously published ileal digestible values predicted to optimize broiler growth (Lemme et al., 2004). No CP minimum was imposed in the nutrient matrix, and amino acid supplements of DL-Met, L-Lys SO_4, and L-Thr were allowed to enter the ingredient matrix. The digestible amino acid minimums of Lemme et al. (2004) represented the H amino acid density dietary treatment. The digestible amino acid minimums were decreased by 10% to derive the M amino acid density dietary treatment representing amino acid needs closely resembling levels typically employed in practice (Kidd et al., 2004). Before constructing least-cost experimental diets, the total amount of soybean meal and poultry meal to be used for the study was acquired and analyzed for all amino acids (Llames and Fontaine, 1994) and CP (AOAC, 1995). Percentage digestible coefficients (Lemme et al., 2004) were multiplied by the analyzed amino acid levels of the former ingredients to calculate percentage digestible amino acid values. All diets were mixed in a horizontal mixer and steam-pelleted. During pelleting, composite samples of all diets were obtained and frozen until analysis of CP (AOAC, 1995) and amino acids (Llames and Fontaine, 1994) could be performed. The 1 to 5 and 6 to 14 d feeds were fed as crumbles.

Birds received diets from 1 to 5, 6 to 14, 15 to 35, 36 to 45, and 46 to 55 d of age, resulting in 5 feed phases. The H and M dietary treatments were fed in various phases throughout the bird's life, resulting in 6 treatments: MMMMM, HMMMM, HHMMM, HHHMM, HHHHM, and HHHHH. Hence, 6 dietary × 2 gender treatments resulted in 12 treatments each having 12 replicate pens.

Measurements

Pen weights and feed consumption were obtained on 5, 14, 35, 45, and 55 d. Pen feed consumption divided by pen BW was used to calculate feed conversion. Mortality was collected twice daily, and the BW of dead birds was recorded. On d 35 and 55, 4 randomly selected birds per pen were weighed and processed. Birds were then wing-banded and placed in coops for 12 h. At the pilot processing facility, birds were bled with an electric knife by severing the jugular vein, scalded for 30 s, defeathered in a rotary picker for 60 s, and manually eviscerated. Carcasses and manually removed abdominal fat were weighed. Carcasses were chilled in an air chiller (1.7°C) for 12 h and then manually deboned. Carcass parts collected and weighed were drumsticks, saddle (bone-in and skin-on thighs and lower back), wings, and breast (boneless and skinless pectoralis major and minor). Carcass parts relative to live BW of processed birds (yield) and their absolute weights are presented.

Economic Model Program

Two programs were created to assess monetary income for broiler chickens in small-bird (1.5 kg/bird) and deboned markets (3.0 kg/bird) as affected by dietary amino acid density. Measurements obtained in the experiment presented herein that were used to establish the outcome of amino acid density diets in the programs were BW at d 35 and 55, feed conversion for the 1 to 35 and 1 to 55 d periods, carcass weight and yield at 35 d, and total breast meat weight and yield at 55 d. Feed ingredient prices from November 2004 (Feedstuffs, 2004) were used to calculate feed costs. The prices ($) of amino acid contributing ingredients that varied with diet density treatments per kilogram were corn, 0.078; soybean meal, 0.187; poultry meal, 0.226; DL-Met, 2.094; L-Lys•HCl, 1.764; and L-Thr, 5.512. The price of L-Lys SO_4 (50.7% L-Lys) was calculated based on L-Lys HCl containing 78.8% L-Lys. November 2004 reference prices for broiler chicken items were taken from USDA (2004). Carcass and total breast meat (skinless and boneless) values were $1.433 and $3.153/kg, respectively. The economic programs were created in Microsoft Excel[6] using mathematical calculations of the former values to calculate: feed cost per kg live BW, feed cost/kg carcass, feed cost/kg total breast meat, income over feed costs per kg carcass, income over feed costs per kg total breast meat, and income over feed costs per bird.

[6]Redmond, WA.

Statistical Analysis

Pen was the experimental unit for all analyses. The design was a randomized complete block. The 12 treatments of the factorial arrangement of 2 genders and 6 dietary amino acid density treatments were analyzed using the GLM procedure of SAS (SAS Institute, 1998) by the following model:

$$Y_{ijk} = \mu + G_i + D_j + GD_{ij} + e_{ijk}$$

where μ is the common mean; G_i is the effect of the *i*th gender; D_j is the effect of the *j*th diet; GD_{ij} is the interactive effect between the *i*th gender and the *j*th diet; and e_{ijk} is random error. However, because dietary treatments were implemented in phases, the factorial array of gender × diet treatments was as follows: 1 to 5 d, 2 × 2; 6 to 14 d, 2 × 3; 15 to 35 d, 2 × 4; 36 to 45 d, 2 × 5; and 46 to 55 d, 2 × 6. Differences among means ($P \le 0.05$) were separated with repeated t test using the LSMEANS option of SAS (SAS Institute, 1998).

RESULTS

Analysis of Experimental Diets

Analyzed composition of the experimental diets is presented in Table 1. Analyzed differences in amino acids between H and M treatment diets were approximately 10%, agreeing closely with calculated treatment projections. Analyzed Lys from 1 to 5, 6 to 14, 15 to 35, 36 to 45, and 46 to 55 d were 1.38, 1.36, 1.23, 1.13, and 1.09% for the H diets and 1.28, 1.24, 1.05, 1.06, and 1.01% for the M diets.

Interactive Effects between Gender and Diet

At d 5, male broilers fed M diets were heavier ($P \le 0.05$) than female broilers fed M diets, but male and female BW was equal when fed the H diets (Table 2). However, male broilers had lower ($P \le 0.05$) feed conversion than female broilers when fed H, but not M diets. Female broilers fed MMMMM, HMMMM, and HHHHM, and male broilers fed HMMMM and HHHMM had lower ($P \le 0.05$) wing yield than male broilers fed HHHHM. Male broilers fed HHMMM and HHHHH had greater ($P \le 0.05$) tender weights than female broilers fed MMMMM, HMMMM, HHMMM, HHHMM, and HHHHH, but not female broilers fed HHHHM. Male broilers fed HHMMM and HHHHH had heavier ($P \le 0.05$) tender weights than female broilers fed all diets except HHHHM. However, all female broilers, except those fed MMMMM, had higher

TABLE 2. Dietary amino acid density × gender interactions

Measurement	Dietary treatments for the 1 to 5 d live performance interactions[1]						SEM
	M	H					
BW, kg/bird							
Female	0.104[c]	0.106[bc]					0.0008
Male	0.109[a]	0.107[ab]					
Feed conversion, kg:kg[2]							
Female	0.584[bc]	0.565[b]					0.0098
Male	0.606[c]	0.546[a]					
	Dietary treatments for the 55-d processing interactions[1]						
	MMMMM	HMMMM	HHMMM	HHHMM	HHHHM	HHHHH	
Wings, %							
Female	8.03[bc]	8.00[c]	8.12[abc]	8.15[abc]	7.99[c]	8.18[ab]	0.059
Male	8.13[abc]	8.08[bc]	8.14[abc]	8.06[bc]	8.27[a]	8.16[ab]	
Tender, kg[3]							
Female	0.115[f]	0.121[def]	0.118[ef]	0.123[cd]	0.130[abc]	0.127[bcd]	0.0028
Male	0.129[abc]	0.132[ab]	0.135[a]	0.134[ab]	0.129[abc]	0.134[a]	
Tenders, %[4]							
Female	4.12[c]	4.36[b]	4.32[b]	4.46[ab]	4.61[a]	4.55[a]	0.057
Male	3.93[d]	4.00[cd]	4.08[cd]	3.99[cd]	3.99[cd]	4.06[cd]	

[a,b,c,d,e,f]Means within a group of rows for a given measurement not sharing a common superscript differ ($P \leq 0.05$).

[1]Dietary treatments represented H (high) and M (moderate) amino acid density. The dietary treatment combinations fed to broilers in various phases and their replications (replications per dietary main effect treatment) were M (24) and H (120) from 1 to 5 d; MM (24), HM (24), and HH (96) from 6 to 14 d; MMM (24); HMM (24), HHM (24), and HHH (72) from 15 to 35 d; MMMM (24), HMMM (24), HHMM (24), HHHM (24), and HHHH (48) from 36 to 44 d; and MMMMM (24), HMMMM (24), HHMMM (24), HHHMM (24), HHHHM (24), and HHHHH (24) from 46 to 55 d.

[2]Feed conversion corrected for mortality adjusted to the weight of the pen average.

[3]Tender represents pectoralis minor weight.

[4]Tender represents pectoralis minor weight relative to BW at processing.

($P \leq 0.05$) tender yields than male broilers regardless of diet fed.

Gender Effects

Male broilers were heavier ($P \leq 0.05$) and had lower ($P \leq 0.05$) feed conversion than female broilers (Table 3). Mortality did not differ ($P > 0.05$) between treatments. Male broilers had less ($P \leq 0.05$) abdominal fat at 35 and 55 d in compared with female broilers. Although breast meat yield did not differ at d 35 ($P > 0.05$), female broilers had greater ($P \leq 0.05$) breast meat yield than male broilers at d 55.

Amino Acid Diet Density Effects

Dietary amino acid density did not impact 5 d BW (Table 4). Day 14, 35, and 45 BW responses were highest ($P \leq 0.05$) in broilers fed HH, HHH, and HHHM, respectively. However, d 55 BW did not differ ($P > 0.05$) among treatments. Feed conversion was lower ($P \leq 0.05$) from 1 to 5, 1 to 14, 1 to 35, 1 to 45, and 1 to 55 d of age in birds fed H, HH, HHH, HHHM, and HHHHH, respectively, compared with birds fed all M diets. Differences in mortality ($P > 0.05$) did not occur among treatments.

Improvements ($P \leq 0.05$) in 35 d carcass weight, fat weight, percentage fat, fillet weight, tender weight, tender

TABLE 3. Male and female broiler live performance and processing responses[1]

	55 d live performance			Processing attributes[2]			
				35 d (% of BW)		55 d (% of BW)	
Gender	BW (kg)	FCR (kg:kg)	Mortality (%)	Abdominal fat	Breast meat	Abdominal fat	Breast meat
Female	2.898[b]	1.857[b]	7.86	1.92[b]	19.21	2.58[b]	21.37[a]
Male	3.372[a]	1.815[a]	9.90	1.77[a]	18.98	2.17[a]	20.67[b]
SEM	0.0199	0.0056	0.901	0.028	0.098	0.033	0.089

[a,b]Means within a column not sharing a common superscript differ ($P \leq 0.05$).

[1]Main effect gender treatments (72 replicate pens per gender) BW, FCR (corrected feed conversion ratio), and mortality were measured at d 55.

[2]Processing measurements were obtained on 4 randomly selected birds per pen at d 35 or 55. Breast meat represents pectoralis major + pectoralis minor.

TABLE 4. BW, corrected feed conversion, and mortality of broilers fed various amino acid density treatments from 1 to 55 d

	Dietary treatments[1]						
Day or period (phases)[1]	MMMMM	HMMMM	HHMMM	HHHMM	HHHHM	HHHHH	SEM
BW, kg/bird							
5 d (P)	0.106			0.106			0.0006
14 d (P, S)	0.369[b]	0.369[b]		0.378[a]			0.0021
35 d (P, S, G)	1.579[b]	1.569[b]	1.595[b]		1.719[a]		0.0123
45 d (P, S, G, F)	2.231[b]	2.262[b]	2.281[b]	2.422[a]	2.399[a]		0.0236
55 d (P, S, G, F, WD)	3.096	3.146	3.091	3.183	3.136	3.160	0.0345
Feed conversion, kg:kg[2]							
1 to 5 d (P)	0.595[b]			0.555[a]			0.0069
1 to 14 d (P, S)	1.106[b]	1.097[b]		1.052[a]			0.0058
1 to 35 d (P, S, G)	1.594[b]	1.607[b]	1.581[b]		1.485[a]		0.0096
1 to 45 d (P, S, G, F)	1.710[b]	1.697[b]	1.694[b]	1.591[a]	1.590[a]		0.0133
1 to 55 d (P, S, G, F, WD)	1.844[b]	1.843[b]	1.852[b]	1.839[b]	1.838[b]	1.799[a]	0.0097
Mortality, %							
1 to 5 d (P)	2.08			2.13			0.532
1 to 14 d (P, S)	6.48	6.02		4.69			0.939
1 to 35 d (P, S, G)	7.87	8.33	5.09		6.26		1.176
1 to 45 d (P, S, G, F)	8.12	9.04	6.50	7.08	6.61		1.296
1 to 55 d (P, S, G, F, WD)	8.57	10.94	7.26	8.57	7.74	10.20	1.556

[a,b]Means within a row not sharing a common superscript differ ($P \leq 0.05$).

[1]Dietary treatments represented H (high) and M (moderate) amino acid density in the following phases: P, prestarter, S, starter, G, grower, F, finisher, and W, withdrawal. The dietary treatment combinations fed to broilers in various phases and their replications (replications/dietary main effect treatment) were: M (24) and H (120) from 1 to 5 d; MM (24), HM (24), and HH (96) from 6 to 14 d; MMM (24); HMM (24), HHM (24), and HHH (72) from 15 to 35 d.; MMMM (24), HMMM (24), HHMM (24), HHHM (24), and HHHH (48) from 36 to 44 d; and MMMMM (24), HMMMM (24), HHMMM (24), HHHMM (24), HHHHM (24), and HHHHH (24) from 46 to 55 d.

[2]Feed conversion corrected for mortality adjusted to the weight of the pen average.

yield, total breast weight, total breast yield, drumstick weight, saddle weight, and wing weight were noted in broilers fed HHH diets (Table 5). Broilers fed HHH had higher ($P \leq 0.05$) carcass and fillet yields than broilers fed MMM and HMM, and broilers fed HHM had intermediate responses. Saddle and wing yields did not differ ($P > 0.05$) among treatments.

Broilers fed HHHMM and HHHHM had the highest carcass yield at d 55 (Table 6). Broilers fed HHHHH had reduced ($P \leq 0.05$) percentage abdominal fat in compari-

TABLE 5. Processing attributes (d 35) of broilers fed various amino acid density treatments from 1 to 35 d

	Dietary treatments[1]				
Parameter[2]	MMM	HMM	HHM	HHH	SEM
Carcass, kg	1.085[b]	1.092[b]	1.103[b]	1.167[a]	0.0122
Carcass, %	68.34[b]	68.29[b]	68.46[ab]	68.79[a]	0.161
Fat, kg	0.030[b]	0.030[b]	0.031[b]	0.027[a]	0.0007
Fat, %	1.93[b]	1.89[b]	1.93[b]	1.61[a]	0.038
Fillet, kg	0.243[b]	0.245[b]	0.248[b]	0.266[a]	0.0037
Fillet, %	15.26[b]	15.29[b]	15.38[ab]	15.66[a]	0.125
Tender, kg	0.057[b]	0.059[b]	0.059[b]	0.064[a]	0.0009
Tender, %	3.63[b]	3.69[b]	3.67[b]	3.80[a]	0.033
Breast, kg	0.300[b]	0.304[b]	0.307[b]	0.330[a]	0.0043
Breast, %	18.89[b]	18.98[b]	19.05[b]	19.46[a]	0.134
Drumsticks, kg	0.151[b]	0.152[b]	0.155[b]	0.164[a]	0.0016
Drumsticks, %	9.55[ab]	9.51[b]	9.60[ab]	9.67[a]	0.050
Saddle, kg	0.308[b]	0.312[b]	0.311[b]	0.332[a]	0.0038
Saddle, %	19.36	19.50	19.25	19.53	0.085
Wings, kg	0.131[b]	0.133[b]	0.134[b]	0.141[a]	0.0014
Wings, %	8.29	8.31	8.33	8.33	0.043

[a,b]Means within a row not sharing a common superscript differ ($P \leq 0.05$).

[1]Dietary treatments represented H (high) and M (moderate) amino acid density. The dietary treatment combinations fed to broilers in various phases and their replications (replications/dietary main effect treatment) were M (24) and H (120) from 1 to 5 d; MM (24), HM (24), and HH (96) from 6 to 14 d; MMM (24); HMM (24), HHM (24), and HHH (72) from 15 to 35 d.

[2]Parameters expressed relative to live BW at processing. Carcass does not include abdominal fat, intestines, and internal organs; fat represents abdominal fat; fillet represents pectoralis major; tender represents pectoralis minor; breast represents pectoralis major + pectoralis minor; saddle represents thighs + lower back.

TABLE 6. Processing attributes (d 55) of broilers fed various amino acid density treatments from 1 to 55 d

Parameter[2]	Dietary treatments[1]						
	MMMMM	HMMMM	HHMMM	HHHMM	HHHHM	HHHHH	SEM
Carcass, kg	2.167	2.180	2.161	2.210	2.187	2.197	0.0256
Carcass, %	71.46[c]	71.57[bc]	71.60[bc]	72.08[a]	72.14[a]	71.95[ab]	0.157
Fat, kg	0.072	0.076	0.074	0.072	0.069	0.068	0.0021
Fat, %	2.39[bc]	2.51[c]	2.46[c]	2.36[abc]	2.29[ab]	2.22[a]	0.057
Fillet, kg	0.509	0.508	0.504	0.519	0.509	0.519	0.0078
Fillet, %	16.78	16.69	16.70	16.93	16.78	17.01	0.136
Tender, kg	0.122[b]	0.127[ab]	0.126[ab]	0.129[a]	0.130[a]	0.131[a]	0.0020
Tender, %	4.02[c]	4.18[b]	4.20[ab]	4.22[ab]	4.30[a]	4.30[a]	0.040
Breast, kg	0.631	0.635	0.630	0.648	0.639	0.649	0.0094
Breast, %	20.80	20.86	20.90	21.15	21.08	21.31	0.154
Drumsticks, kg	0.299	0.299	0.296	0.302	0.302	0.302	0.0032
Drumsticks, %	9.85	9.80	9.79	9.84	9.96	9.87	0.058
Saddle, kg	0.631	0.637	0.628	0.639	0.633	0.631	0.0084
Saddle, %	20.80	20.89	20.77	20.82	20.85	20.63	0.105
Wings, kg	0.245	0.244	0.245	0.248	0.246	0.249	0.0027
Wings, %	8.08	8.04	8.13	8.11	8.13	8.17	0.041

[a,b,c]Means within a row not sharing a common superscript differ ($P \le 0.05$).

[1]Dietary treatments represented H (high) and M (moderate) amino acid density. The dietary treatment combinations fed to broilers in various phases and their replications (replications/dietary main effect treatment) were M (24) and H (120) from 1 to 5 d; MM (24), HM (24), and HH (96) from 6 to 14 d; MMM (24); HMM (24), HHM (24), and HHH (72) from 15 to 35 d; MMMM (24), HMMM (24), HHMM (24), HHHM (24), and HHHH (48) from 36 to 44 d; and MMMMM (24), HMMMM (24), HHMMM (24), HHHMM (24), HHHHM (24), and HHHHH (24) from 46 to 55 d.

[2]Parameters expressed relative to live BW at processing. Carcass does not include abdominal fat, intestines, and internal organs; fat represents abdominal fat; fillet represents pectoralis major; tender represents pectoralis minor; breast represents pectoralis major + pectoralis minor; saddle represents thighs + lower back.

son to broilers fed MMMMM, HMMMM, HHMMM, and broilers fed HHHMM and HHHHM had intermediate values. Broilers fed HHHHH, HHHHM, and HHHMM had greater ($P \le 0.05$) tender weights than broilers fed MMMMM, whereas broilers fed HHHHH and HHHHM had greater ($P \le 0.05$) tender yields than broilers fed HMMMM and MMMMM. Differences ($P \le 0.05$) in other processing measurements at d 55 did not occur among treatments.

DISCUSSION

The purpose of this research was to assess potential effects of Ross × 708 broilers to dietary amino acid density. Much research has been conducted to evaluate modern commercial broiler strains to diets differing in amino acids and protein (Smith and Pesti, 1998; Smith et al., 1998; Bartov and Plavnik, 1998; Dozier and Moran, 2001; Lemme et al., 2003; Corzo et al., 2004; Kidd et al., 2004), but research addressing the dietary responsiveness of the Ross × 708 broiler is sparse. Similar to the findings of the former research, feed conversion and abdominal fat, in addition to some carcass parameters, were lowered in the current study as dietary amino acid density increased.

Male broilers typically have more whole body protein and less whole body fat than female broilers. Although interactions occurred at 55 d for tender weight and wing and tender yield, gender BW, feed conversion, and abdominal fat were not affected in differing degrees by amino acid density in any phases of growth. All H diets had improved broiler growth and carcass responses early in life and to a lesser extent, later in life (Tables 2, 4, 5, and 6). At d 35, but not d 55 processing, the increased amino acid density improved carcass weights and yields. Hence, the responsiveness of broilers to amino acid density in the current study is different from published research using a similar design, but a different

TABLE 7. Impact of dietary amino acid density on income for carcass at d 35[1]

Economic value, $[2]	MMM	HMM	HHM	HHH
Feed costs/907.2 kg	128.85	129.03	130.12	136.35
Feed costs/kg	0.1420	0.1422	0.1434	0.1503
Feed costs/kg live BW[3]	0.2264	0.2286	0.2269	0.2231
Feed costs/kg carcass	0.3313	0.3347	0.3313	0.3245
Income over feed costs/kg carcass	1.102	1.098	1.102	1.109
Income over feed costs/bird	1.189	1.177	1.203	1.311

[1]Represents the weight of the carcass minus abdominal fat pad, intestines, and internal organs.

[2]Economic value for carcass is $1.433/kg (USDA, 2004). Referenced prices for all feed ingredients were taken from Feedstuffs (2004).

[3]Represents BW at d 35 (Table 4).

TABLE 8. Impact of dietary amino acid density on income for total breast meat (WM) at d 55[1]

Economic value, $[2]	MMMMM	HMMMM	HHMMM	HHHMM	HHHHM	HHHHH
Feed costs/907.2 kg	127.34	127.43	127.89	130.37	132.01	134.52
Feed costs/kg	0.1404	0.1405	0.1410	0.1437	0.1455	0.1483
Feed costs/kg live BW	0.2588	0.2588	0.2610	0.2643	0.2674	0.2668
Feed costs/kg WM	1.2445	1.2410	1.2491	1.2496	1.2687	1.2518
Income over feed costs/kg WM	1.909	1.911	1.903	1.903	1.883	1.900
Income over feed costs/bird	1.229	1.254	1.230	1.281	1.245	1.280

[1]WM represents total breast meat (skinless and boneless pectoralis major and minor).

[2]Economic value for broiler breast meat is $3.153/kg (USDA, 2004). Referenced prices for all feed ingredients were taken from Feedstuffs (2004).

[3]Represents BW at d 55 (Table 4).

strain of broiler. For example, Corzo et al. (2004) fed diets to Arbor Acres Plus broilers and noted improved d 49 breast meat yield to diets high in amino acid density (18.90% yield) vs. diets low in amino acid density (16.50% yield), with breast meat yield of broilers fed medium amino acid density being intermediate (18.60% yield). Similar diets to those presented by Corzo et al. (2004) were used by Kidd et al. (2004) to measure amino acid responsiveness to Ross × 508 males and female broilers. It was found that high-density diets throughout life optimized breast meat yield (breast meat yields in birds fed H, M, and low amino acid density of 20.5, 19.4, and 17.5%, respectively), and decreasing amino acid density resulted in reduced BW, feed conversion, and meat yields (Kidd et al. 2004). However, dietary treatment differences in d 55 breast meat yield in the current study did not occur. Amino acid levels from 1 to 35 d in the current study and the study of Kidd et al. (2004) were similar, but large treatment differences occurred in amino acids levels from d 36 to trial termination in the study of Kidd et al. (2004) compared with H and M diet differences in the current study. Hence, the lack of response in d-55 BW and breast meat yield in the current study may be due to the H amino acid levels being above the bird's needs. Although the Arbor Acres Plus broiler is a multipurpose strain (Corzo et al., 2004), whereas the Ross × 508 (Kidd et al., 2004) and Ross × 708 broilers are high-yield strains, the current study and former reports point to the importance of optimizing amino acid nutrition early in the bird's life. Moreover, Lys levels in the last two periods (36–55 d) for birds fed M diets (average analyzed Lys of 1.04%) and birds fed H diets (average analyzed Lys of 1.11%) were higher than those typically observed in practice and recommended (NRC, 1994). For example, Corzo et al. (2002) evaluated Lys needs in heavy Ross × 308 male broilers fed diets in an ideal protein balance and found that the NRC (1994) recommendation of 0.85% is adequate for broilers from 42 to 56 d of age.

Broilers fed diets with lower levels of amino acids will have reduced growth and carcass yields, and increased feed conversion. Although feeding amino acid excesses is costly due to small improvements in yield and large increases in diet costs, marginal amino acid levels in low cost diets may be more costly due to reduced economic returns from a loss of saleable meat. Therefore, an economic comparison was done in the current study using published feed ingredient prices (Feedstuffs, 2004) and chicken meat prices (USDA, 2004) from November 2004 (Tables 7 and 8). The average diet costs per US ton ($/907.2 kg of feed) were MMM, $120.76; HMM, $120.82; HHM, $121.08; HHH, $123.51; MMMMM, $120.76; HMMMM, $120.82; HHMMM, $121.08; HHHMM, $123.51; HHHHM, $125.14; and HHHHH, $127.47. Thus, each phase whereby an H amino acid density diet regime was included had increased diet costs. Although diet cost increased, expressing feed costs/kg of BW or carcass at d 35 decreased. The d 55 processing economic calculations differed from those at d 35, as breast meat yield differences ($P \leq 0.05$) did not occur. Furthermore, feed costs per kilogram of BW increased at 55 d as H diets were fed in more phases. However, both 35- and 55-d income over feed costs per bird increased in birds fed all H diets vs birds fed all M diets. Because M and H diets were relatively high in amino acids and balanced (ileal digestible ratios to Lys), it is expected that increased amino acid density in diets that are deficient in some amino acids (Kidd et al., 2004) would result in greater profit. In addition to delineating the importance of not minimizing amino acids early in a broiler's life, these results demonstrate potential positive economic impacts from meeting, rather than exceeding, amino acid needs in high yield broilers.

REFERENCES

AOAC. 1995. Official Methods of Analysis. Official Method 982.30, Section E (A, B, C). 16th ed. Assoc. Off. Anal. Chem., Washington, DC.

Bartov, I., and I. Plavnik. 1998. Moderate excess of dietary protein increases breast meat yield of broiler chicks. Poult. Sci. 77:680–688.

Corzo, A., C. D. McDaniel, M. T. Kidd, E. R. Miller, B. B. Boren, and B. I. Fancher. 2004. Impact of dietary amino acid concentration on growth, carcass yield, and uniformity of broilers. Aust. J. Agric. Res. 55:1133–1138.

Corzo, A., E. T. Moran, Jr., and D. Hoehler, 2002. Lysine need of heavy broiler males applying the ideal protein concept. Poult. Sci. 81:1863–1868.

Dozier, W. A., III., and E. T. Moran, Jr. 2001. Response of early- and late-developing broilers to nutritionally adequate and restrictive feeding regimes during the summer. J. Appl. Poult. Sci. 10:92–98.

Feedstuffs. 2004. Subject: Ingredient market. http://www.feedstuffs.com. Accessed Nov. 2004.

FASS. Guide for the Care and Use of Agriculture Animals in Agricultural Research and Teaching. 1991. 1st rev. ed. Fed. Anim. Sci. Soc., Savoy, IL.

Kidd, M. T., C. D. McDaniel, S. L. Branton, E. R. Miller, B. B. Boren, and B. I. Fancher. 2004. Increasing amino acid density improves live performance and carcass yields of commercial broilers. J. Appl. Poult. Res. 13:593–604.

Lemme, A., S. Mack, P. J. A. Wijtten, D. J. Langhout, G. G. Irish, and A. Petri. 2003. Effects of increasing levels of dietary "ideal protein" on broiler performance. Pages 58–61 in Proc. 15th Aust. Poult. Sci. Symp., Sydney, Australia.

Lemme, A., V. Ravindran, and W. L. Bryden. 2004. Standardized ileal amino acid digestibility of raw materials in broilers. Proc. of the Multi-State Poultry Feeding and Nutrition and Health and Management Conf. and Degussa Corp.'s Technical Symp. Indianapolis, Indiana. CD-ROM.

Llames, C., and J. Fontaine. 1994. Determination of amino acids in feeds: Collaborative study. J. AOAC Int. 77:1362–1402.

Microsoft Excel. 2002. Microsoft Corp., Redmond, WA.

NRC. 1994. Nutrient Requirements of Poultry. 9th Rev. ed. Natl. Acad. Press, Washington, DC.

SAS Institute. 1998. SAS User's Guide: Statistics Version 7.0. SAS Inst., Inc., Cary, NC.

Smith, E. R., and G. M. Pesti. 1998. Influence of broiler strain cross and dietary protein on the performance of broilers. Poult. Sci. 77:276–281.

Smith, E. R., G. M. Pesti, R. I. Bakalli, G. O. Ware, and J. F. M. Menten. 1998. Further studies on the influence of genotype and dietary protein on the performance of broilers. Poult. Sci. 77:1678–1687.

USDA. 2004. USDA Broiler Market News Report. www.ams.usda.gov/marketnews.htm. Accessed Nov. 2004.